

An Integrated Approach to Manage Vibration Risks on Compressors, Pumps, and the Piping System



Background

Vibration is a significant factor contributing to reliability and integrity problems. For example, a vibration-induced piping failure will release gas or liquid that can cause a fire or explosion – an extreme personnel safety issue, production shut-down and multi-million dollar environmental risk.

Many different sources of vibration contribute to this integrity risk, including transient or steady-state fluid flow, pulsations, and mechanical excitations.

Companies understand the importance of mitigating vibration and associated piping failures. They know it involves a small upfront investment by hiring vibration/dynamic design engineers to ensure that vibration and dynamic issues are considered in the design phase. This effort quickly pays off, especially compared to the costs involved in field modifications.

An Integrated Approach to Managing Vibration Risks

Vibration risks affect different areas of a production facility. An integrated approach is needed because different engineering disciplines are involved in the solution (piping/static engineers, structural engineers, rotating engineers, maintenance and reliability/integrity teams). An overview of this approach is given in the table below and more detail is found in the following paragraphs.

INTEGRATED APPROACH TO SOLVE VIBRATION RISKS

STAGE	ENGINEERING REQUIREMENTS (Vibration & Dynamics Issues)		
Planning (FEED)	Vibration/Dynamic Design Review: Identify high risk areas and define requirements of vibration/dynamic engineering analysis.		
Detailed Design	<p>Compressor/Pump Vibration Assessment Evaluate piping layout, pulsation control, surge control, mechanical and skid dynamics, torsional or lateral stress, small bore connections, and other vibration /stress factors. Scope depends on the machine size and application.</p> <p>This work is coordinated with the machine packager and reliability team.</p>	<p>Piping Vibration Assessment Evaluate integrity risks in main piping and small bore connections due to pulsations, flow induced vibration, acoustic induced vibration, transients or water hammer, shell modes, and piping mechanical response.</p> <p>This work is coordinated with the piping/static design team.</p>	<p>Structural or Foundation Dynamic Assessment Evaluate, where needed, the foundation or structural design (e.g., platform, FPSO, pipe rack) and implement changes to avoid resonance. This work is closely integrated with the mechanical and skid dynamics (Compressor/Pump Vibration Assessment)</p> <p>This work is coordinated with the structural team.</p>
Operations and Maintenance	<p>Site Vibration Requirements</p> <ul style="list-style-type: none"> • Vibration baseline assessment (including piping and machinery vibration) • Troubleshooting and resolving vibration issues • Monitoring programs 		

Planning – Vibration/Dynamic Design Review

During the planning stage (i.e., Front End Engineering & Design, or FEED) owners or their Engineering Consultants contact BETA, a vibration consultant, to provide recommendations for vibration related requirements. This can include machinery orientation and initial module layout, application advice, vibration requirements and scope, timing of critical path activities, and other initial design considerations.

Detailed Design

Compressor/Pump Vibration Assessment Once the project moves into the Detailed Design stage, the larger compressors and pumps will require specialized vibration design analysis (pulsation, mechanical resonance, compressor surge analysis, water hammer, etc.). The scope of work is dependent on the type of machine, size, and application. The recommended modifications are coordinated with the designated machinery packager and the Engineering Consultant. Early involvement of the vibration consultant enables time for finalizing coupling design, pulsation control vessel sizing, surge control components, pipe support locations and designs, skid design and dynamics, or other critical activities.

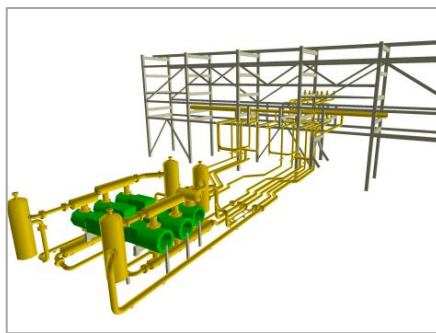
Piping Vibration Assessment The piping system faces many vibration related risks – both in the main piping and with small bore connections. The vibration or dynamic assessment can employ the methodology proposed in the Energy Institute Guideline (2008) to evaluate excitation sources including pulsations, mechanical resonance, acoustic induced vibration, flow induced vibration, turbulent flow, water hammer, cavitation, etc. High risk areas (high likelihood of failure) require advanced studies (or investigation), software and analytical tools, and sound field experience in piping vibration to ensure practical recommendations.

Structural or Foundation Dynamic Assessment A Dynamic Foundation or Structural Assessment may be required, especially when reciprocating equipment, engines, and other dynamic loads are employed. These engineering studies are directly coordinated with the vibration/dynamic design of the compressor or pump package (Compressor/Pump Vibration Assessment above).

Using the same vibration consultant for the assessment of all three vibration components (pumps and compressors, piping, and structure/foundation) is recommended for two main reasons:

1. To ensure a coordinated design approach and recommendations, and
2. Because these studies share key information in regards to boundary conditions, dynamic forces, forced response methodology, and Finite Element models.

Many problems have occurred when different companies are involved in the vibration and dynamic analysis due to different methodologies, assumptions, guidelines, and lack of coordination.



Examples where an integrated approach is used to mitigate vibration risks in the piping system, compressor and pump skids, offshore & onshore foundations, and elevated structural supports.

Operations and Maintenance Support

Many production facilities do not have engineers with the right experience to solve complex dynamic issues or vibration problems. In these cases, the operations and reliability teams draw on assistance from a vibration consultant, like BETA, to support these activities:

- **Baseline Vibration Assessments.** Using multi-channel analyzers and other equipment, vibration and stress measurements are taken at key locations to evaluate and mitigate integrity risks.

- **Troubleshooting.** Vibration-based problems often required advanced tools and techniques to assess the root cause of the problem and evaluate the best solution. Trial and error approaches seldom work in these cases due to the complexity of issues involved.
- **Ongoing Monitoring Programs.** A cost-effective vibration and equipment monitoring program pays dividends over the life of the operation. Practical and cost-effective monitoring solutions are available, even for remote locations.

Ideas to Get Started

Best-in-Class companies follow this integrated approach so that a common methodology is applied by different stakeholders. Here are some ideas to get started.

- Assign the champion(s) to create an overall plan is a useful first step.
- Educate the team is important. Before drilling down into the technical details, it is helpful to explain the basic dynamic/vibration risks facing the facility, which standards apply, and how these problems are solved. Many engineers and project managers lack awareness and experience in this area, so a one to two hour seminar can create a common understanding and buy-in.
- Correctly specify the required vibration scope into the initial FEED and design steps. For many projects, vibration issues are an afterthought. This means it is too late to make minor piping or support changes. Early involvement avoids this common problem, and saves time and money later.

This cross-functional approach avoids issues “falling through the cracks” and averts multi-million dollar expenses due to piping fatigue failure and machinery downtime.

For More Information

Refer to BETA’s website for related articles and information on the vibration assessments:

- “Piping Vibration Risks and Integrity Assessment”. This article summarizes the relevant excitation sources, approach and requirements for piping vibration studies.
- “Structural Vibration and Ways to Avoid It”. This article explains structural resonance and the difference between dynamic structural analysis and the static design studies.
- Articles, videos, specifications and other technical resources to control vibration on compressors and pumps.

Beta Machinery Analysis

BETA provides specialized design and field based engineers to ensure a truly integrated vibration solution. Our engineering services are applied to:

- **New Projects.** The ideal time to avoid vibration problems is during the design stage when minor changes to piping, supports, and other simple modifications are easy (and cost-effective) to implement.
- **Brownfield Projects or Equipment Modifications.** These projects involve changes to the equipment, piping system, and operating conditions – all of which can introduce new vibration issues.
- **Operations and Maintenance.** Commissioning, troubleshooting and monitoring activities require specialized experience to identify the root cause of problems and provide a practical path to improving the system.

BETA’s engineering solutions provide a very high payback for owners and the Company is the trusted advisor for many of the world’s largest petroleum-based companies.